Renewable and Sustainable Energy Reviews 38 (2014) 700–705

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A comparative study on energy income estimation: A case study in Turkey

M. Ak, A.M. Yanmaz*, E. Kentel

Civil Engineering Department, Middle East Technical University, 06800 Ankara, Turkey

ARTICLE INFO

Article history:
Received 24 August 2012
Received in revised form
20 May 2014
Accepted 6 July 2014
Available online 24 July 2014

Keywords:
Hydropower
Energy income estimation
Pricing

ABSTRACT

Hydropower is the main domestic energy resource of Turkey. The total gross and the economically feasible hydropower potentials of Turkey are estimated as 433 TWh/yr and 127 TWh/yr, respectively, by the General Directorate of State Hydraulic Works (DSI) of the Ministry of Forestry and Water Affairs.[1] Approximately 35% of the economically feasible hydropower potential is currently being utilized. The government accelerated the development of the unused potential by enabling the private sector to build and operate hydroelectric power plants. The primary goal of a feasibility study is the determination of the best installed capacity through economic analysis, which is based on evaluation of energy incomes and investment costs associated with alternative installed capacities. Generally, it is relatively easy to realistically estimate the investment costs. On the other hand, energy income estimation is not a straight forward process; a number of different methods which result in different income estimates are being used in Turkey. The General Directorate of Renewable Energy (YEGM) of the Ministry and Natural Resources and DSI recommend similar methods for energy income estimation based on firm and secondary energy generations. However, suggested unit prices for firm and secondary energy generations by DSI and YEGM are quite different, which results in different energy income estimations. Apart from these two methods, consultancy firms, unlike DSI and YEGM, use a single unit price for energy without making any distinction between firm and secondary energies. In all three methods fixed energy prices are used. Nevertheless these approaches do not represent the current situation in Turkey, since the electricity market allows development of hourly electricity prices. In this study, a new energy income estimation method which utilizes hourly electricity prices, called the Variable Price Method is developed. Results of these four methods are compared for a case study, namely Altiparmak Hydroelectric Power Plant.

Contents

* Corresponding author. Tel.: +90 312 2105444; fax: +90 312 2107956.
E-mail address: myanz@metu.edu.tr (A.M. Yanmaz).

[1] Ozkaldi, A. General Directorate of State Hydraulic Works, http://www.dsi.gov.tr/docs/sunumlar/enerji-sunumu—27-11-2011.ppt?sfvrsn=2, 27 October 2011 [accessed 5.05.13].

http://dx.doi.org/10.1016/j.rser.2014.07.012
1364-0321/

1. Introduction

Hydropower is Turkey's main domestic energy resource. DSI is the primary responsible executive state agency for planning, operation and management of water resources in the country. According to DSI, approximately 65% of the economically feasible hydropower potential of Turkey is undeveloped [1]. This makes the funding of hydropower projects by the private sector very important in developing countries, such as Turkey [2]. Therefore, the government accelerated the development of the unused hydropower potential [3] by enacting the Electricity Market Law no. 4628 in 2001 [4], which enables the private sector to build and operate hydroelectric power plants. Moreover, with the publication of the Renewable Energy Law no. 5346 in May 2005 [4], the government guarantees the purchase of electricity from production companies at a price of 7.3 US cent/Kwh for 10 years. As a result of these laws, investments in hydroelectric power plants (HEPPs) increased and the number of HEPP projects under the planning and construction stages reached 1084 and 256, respectively [5]. A summary of HEPP projects in Turkey is shown in Table 1.

Before any HEPP project is constructed, a feasibility study needs to be conducted. Such assessment is commonly carried out by a private engineering company or a consultancy firm. An economic analysis is carried out in the feasibility study to determine the best installed capacity for the HEPP. The economic analysis is based on the evaluation of energy incomes and investment costs associated with alternative installed capacities. Generally, it is relatively easy to make realistic estimates of a HEPP's investment cost as this can be estimated from construction unit prices determined by DSI or by using bids collected from the market. On the other hand, energy income estimation is not a straightforward process; a number of different methods, which result in different income estimates, are being used in Turkey.

The General Directorate of Renewable Energy (formerly called General Directorate of Electrical Power Resources Survey and Development Administration, EIEI) and DSI recommend similar methods for energy income estimation based on firm and secondary energy generations [6]. However, firm and secondary energy generation unit prices suggested by both YEGM and DSI are quite different, which results in different energy income estimates. Apart from these two methods, private engineering companies and consultancy firms, unlike these two government bodies, use a single unit price (hereafter referred to as Single Price Method, SPM) for energy income estimation without making any distinction between firm and secondary energies. For example, both Hidromark and Eser Project, prominent Turkish private companies in the sector, used single unit price for energy in the feasibility studies they carried out for Balkusan and Ekincik HEPPs, respectively [7,8].

Each consulting company is free to conduct HEPP feasibility analyses with the fixed price of its choice. Due to free market principles, DSI imposes no restrictions on such price. Ideally, consulting companies investigate previous electricity prices and choose reasonable price estimates to use in their feasibility studies. However, such an arbitrary approach results in the utilization of different price estimates by different companies for different projects. Moreover, starting in December 2009, the Turkish electricity market has undergone a comprehensive structural change with the enactment of the Day Ahead Planning and Balancing Power sub-markets [9]. Thus, since early 2010, hourly electricity prices have been used for electricity trading. Given such reforms, we believe the integration of hourly electricity prices into feasibility analyses will result in more realistic energy income estimates for HEPPs. As such, this study develops a new energy income estimation method that uses hourly electricity prices, the VPM. As a case study, economic analysis for two different formulations of Altiparmak HEPP is carried out using four different energy income estimation methods, namely the SPM, the YEGM method, the DSI method and the VPM, and the results are compared.

Table 1
HEPP projects in Turkey [5].

Potential	Number of HEPP	Total installed capacity (MW)	Average annual generation (GWh/Year)	Percent (%)
In operation	303	17,372	62,000	38
Under construction	256	10,590	35,000	21
Project phase	1084	19,535	67,000	41
Total	1643	47,497	164,000	100

2. Altiparmak dam

The potential of renewable energy sources in Turkey is large and hydropower represents a great portion of it [10–13]. Currently, there are many hydropower projects in the design and construction stages in Turkey [14,15] and Altiparmak HEPP is one, currently in its design stage. This project aims to develop the hydropower potential between the elevations of 1230 m and 840 m of Parhal Stream, a branch of Coruh River in Artvin [16]. YEGM and ANC Energy, a private company intending to construct this power plant, have developed two alternative formulations for the Altiparmak HEPP as shown in Fig. 1. Fig. 1 shows how ANC Energy recommended a relatively different model to that proposed by YEGM, in order to shorten the construction time and the costs of dam body and expropriation [17]. YEGM formulation is composed of an arch dam whose thalweg elevation is 1095 m. The power plant is located at Sarıgöl and a 6785 m long energy tunnel connects the reservoir to the power plant. The length of the penstock is 467 m. On the other hand ANC planned a roller compacted concrete dam at a thalweg elevation of 1160 m. The energy tunnel and the penstock lengths for ANC formulation are 8635 m and 687 m, respectively. Basic characteristics of these formulations are shown in Table 2.

As shown in Table 2, the optimum installed capacities recommended by YEGM and ANC Energy for the Altiparmak HEPP are 50 MW and 70 MW, respectively. Although the formulations are similar to each other, the estimated optimum installed capacities are different. The reservoir storage capacity of the YEGM project is bigger than that of the ANC Energy project. Therefore, the inflow can be regulated more efficiently with the YEGM formulation; so its optimum installed capacity is expected to be higher. However, as can be seen from Table 2, ANC Energy recommended a higher installed capacity for the project. This discrepancy arises from the utilization of two different energy income estimation methods. ANC Energy used a fixed price (8.25 US cent/kWh) for estimating the energy income. As explained before, YEGM used its own method which utilizes lower unit prices for firm and secondary energy generations.

3. Feasibility level economic analysis

Most efficient utilization of hydropower energy requires identification of the best installed capacity of a HEPP through economic analysis [18–20]. In the economic analysis, design discharge alternatives are identified first and then the corresponding alternative installed capacities are calculated. Different alternative installed

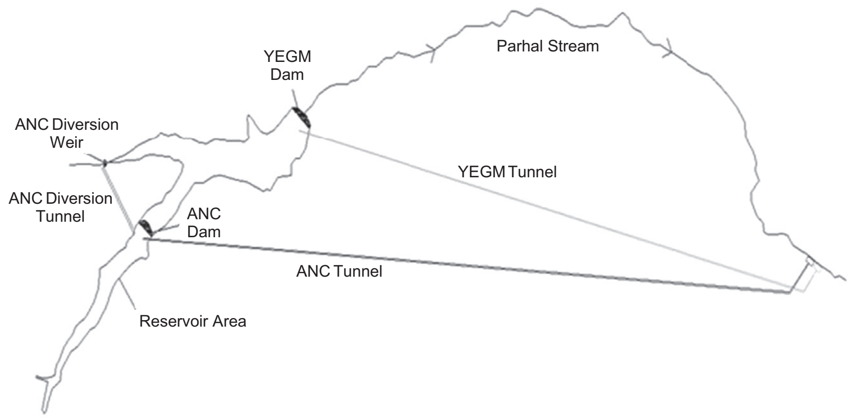

Fig. 1. Altiparmak HEPP formulations developed by YEGM and ANC energy (Not to Scale) [17].

Table 2
Characteristics of YEGM and ANC energy formulations for Altiparmak HEPP.

Physical characteristics	YEGM formulation	ANC formulation
Thalweg elevation (m)	1095	1160
Maximum water elevation (m)	1230	1230
Tailwater elevation (m)	840	840
Drainage basin area (km^2)	317.84	306.67
Maximum reservoir area (km^2)	1.48	0.37
Tunnel length (m)	6785	8635
Active reservoir storage volume (hm^3)	13.99	3.43
Penstock length (m)	467	687
Installed capacity (MW)	**50**	**70**
Construction duration (years)	6	4
Firm energy generation (GWh)	122.50	37.04
Secondary energy generation (GWh)	78.07	161.40
Total energy generation (GWh)	200.57	198.44

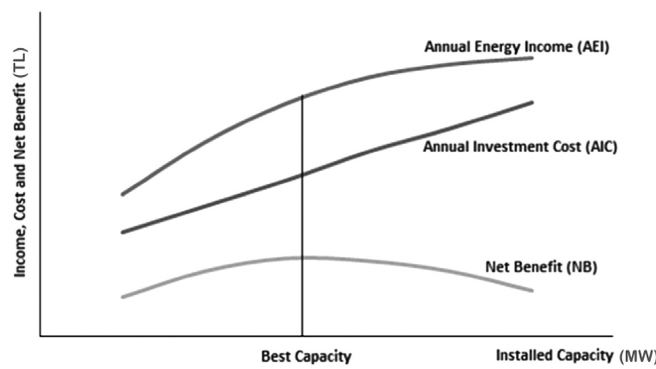

Fig. 2. Relation between cost, income, net benefit and installed capacity for a hydroelectric power plant [21].

capacities result in different annual energy generations, consequently annual energy incomes (AEI) and annual investment costs (AIC). The initial investment costs are converted to equivalent AIC by using an appropriate capital recovery factor (CRF) so that they can be subtracted from the AEI to calculate the net benefit (NB) associated with each alternative installed capacity. The relation among AEI, AIC and NB is shown in Fig. 2. The NB first increases then decreases with installed capacity. The peak of the NB curve corresponds to the optimum installed capacity of the HEPP. Thus, to select the optimum installed capacity, AEI which is a function of the annual energy generation and AIC has to be determined. The AEI curve is a parabola and it levels off after the optimum capacity. In other words, the annual energy generation and the related annual energy income do not change considerably with the increasing installed capacity after the optimum capacity.

In this study, a set of alternative design discharges are selected by using flow-duration curves of the alternative formulations and for this set of alternative design discharges, the corresponding installed capacities are determined. Then for each alternative, AEI and AIC are calculated and the resulting NB is estimated. Installed capacity corresponding to the highest NB is selected as the optimum installed capacity. In this study, the economic life of the project, n is taken as 50 years since Turkey's Energy Market Board Authority assigns licenses to build and operate HEPPs for 49 years. The feasibility report of Altiparmak HEPP was prepared by Yolsu Engineering in 2009 [22] and an interest rate, i of 9.5% was used in that report. To be consistent with the original feasibility report the same interest rate is used here. Then CRF is calculated as 0.096 using $[i(1+i)^n]/[(1+i)^n-1]$.

3.1. Determination of annual energy generation and annual energy income

A reservoir operation study (ROS) needs to be conducted to determine energy income of a hydropower plant. Three commonly used ROS methods are the non-sequential or flow-duration curve method, the sequential streamflow routing (SSR) method and the hybrid method which is the combination of these two [23]. The SSR method is the preferred method for ROS of hydropower projects with storages [24]. Since Altıparmak HEPP has a reservoir, SSR is used to conduct the ROS for Altiparmak HEPP in this study. A spreadsheet is prepared to carry out SSR for monthly time intervals to estimate firm, secondary, and annual energy generations of the project. Then the energy incomes associated with these energy generations corresponding to each alternative installed capacity are determined by using the above-mentioned energy income estimation methods. Four different energy income estimation methods: the YEGM method, the DSI method, the SPM, and the VPM are explained in the following sections.

3.1.1. The YEGM method

Hydropower plants are designed and operated to maximize generation of various forms of energy, such as the firm energy or the average annual energy [24]. Firm energy is defined as the power that can be delivered by a specific plant during a certain period of the day with at least with 95% certainty [25]; while secondary energy is defined as the energy generated in excess of firm energy [26]. The annual average energy is the average energy generated per year.

The YEGM method separates the total energy generation into two parts: firm and secondary energy generations. Firm energy is considered to be more valuable since its generation is guaranteed for a certain period of the day. Therefore, in both YEGM and DSI methods, firm energy is assumed to be financially more beneficial than secondary energy (see Table 3). In addition to firm and secondary energy incomes, YEGM evaluates peak power of a HEPP in its economic analysis. Peak power is calculated by using the following formula [28]:

$$PP = \frac{AFE}{0.33*8760} \tag{1}$$

where *PP* is the peak power (kW) which can usually be generated at about one third of a day [29], 0.33 is a coefficient to account for this peak power definition, AFE is the annual firm energy (kWh), 8760 is the number of hours in a year.

The total annual energy income, AEI is estimated by summing up firm, secondary and peak power incomes:

$$AEI = E_f(p_f) + E_s(p_s) + PP(p_p) \tag{2}$$

where E_f is firm energy generation (kWh), E_s is secondary energy generation (kWh), p_f and p_s are the unit prices for firm and secondary energy generations ($/kWh), respectively, and p_p is the unit price of energy benefit for peak power ($/kW).

3.1.2. The DSI method

Similar to the YEGM, DSI uses firm energy, secondary energy and peak power concepts in estimating the AEI as given in Eq. (2). However, the energy prices (see Table 3) and the estimation of peak power is rather different [28]:

$$PP = IC - \frac{AFE}{0.72*8760} \tag{3}$$

where IC is the installed capacity (kW). According to DSI, peak power is accepted as the difference between the installed capacity and the power which is 38% in excess of the annual firm power.

3.1.3. The single price method (SPM)

Although YEGM and DSI evaluate firm and secondary energies differently, from an investor's point of view, maximizing the net benefit (i.e. average annual energy income) is always the main goal. Thus, the SSR method used in this study is formulated such that it allows simultaneous maximization of firm and secondary energies. The spreadsheet can be used for maximization of the average annual energy generation by assigning zero to firm energy requirement.

SPM is the simplest one among these four methods. A fixed price (i.e. 8.25 US cent/kWh) is assumed for all the energy generated by the HEPP [17]. Then this unit price is multiplied by the annual average energy generated and energy income is estimated. This method does not separate energy into firm and secondary energies but uses annual energy generation. This is the preferred method for the consulting companies that carry out feasibility studies due to its ease.

Table 3
Energy prices for DSI and YEGM methods [6,27].

Type of energy benefit	Prices	
	YEGM	**DSI**
Firm energy	4.5 US cent/kWh	6.0 US cent/kWh
Secondary energy	3.5 US cent/kWh	3.3 US cent/kWh
Peak power	240.0 US $/kW	85.0 US $/kW

3.1.4. The Variable Price Method

A new method, the Variable Price Method which utilizes hourly energy prices is developed in this study as an alternative energy income estimation method. Electricity prices change within a day and from month to month. Variations of hourly electricity prices based on electricity prices observed in Turkey between July 2010 and June 2011 is shown in Fig. 3. These market prices are governed by hourly supplies and demands. Details of the electricity market and how market prices are set can be found in [17,31,32]. Recent developments in the Turkish power market are explained in detail in Ref. [33] as well. As can be seen from Fig. 3, the hourly electricity prices fluctuate considerably in Turkey. The differences between hourly electricity prices may result in increased benefits, especially for HEPPs with storages.

Hours in which the electricity prices are relatively higher are called peak hours, while the rest of the hours are called off-peak hours. The corresponding prices are called peak prices and off-peak prices, respectively [34]. Traditionally, energy income calculations are based on average energy prices [35] as in the SPM. However, this approximation gives higher or lower than actual results due to the fluctuations of the electricity prices within a day. To overcome this problem, peak and off-peak prices were used in various studies [36,37]. Another suggestion was the utilization of varying prices for four six-hour time spans in a day [38]. Since hourly electricity prices are available in Turkey, utilization of these hourly prices in AEI calculations is the most realistic approach. Especially for HEPPs with storages, electricity generation during the peak price hours is possible and will result in increased benefits. The VPM intends to estimate these additional benefits due to selling electricity during hours at which prices reach peak values. Thus, in calculating the monthly energy income, the VPM assumes that the energy is generated and sold starting from the peak price hours. For example, if the HEPP is able to generate electricity only three hours within a day during a specific month, then the HEPP is assumed to generate these three hours when the electricity price per hour is the highest. Using hourly variable prices, energy income of each month of the year within the analysis period is calculated and summed to find annual energy income of that year.

3.2. Determination of annual investment cost (AIC)

Investment costs for each alternative installed capacity are also required to estimate the net benefits. The energy income for each alternative is estimated annually; therefore the initial investment costs need to be converted to the equivalent annual costs. The investment cost of an HEPP is mainly composed of the costs associated with dam body, tunnel, penstock, surge tank, diversion tunnel, power house, turbine, transformer, generator, and expropriation costs. The costs of penstock, powerhouse, turbine, transformer, and generator may change considerably with the installed capacity and for the sake of simplicity, only these costs are taken into consideration in the economic analysis of Altiparmak HEPP. Other costs, not significantly affected by the installed capacity, are neglected in the economic analysis.

3.3. Determination of net benefit (NB)

The net benefits are estimated by subtracting the equivalent annual costs from annual energy incomes. The installed capacity that results in the maximum net benefit is selected as the best installed capacity. The best installed capacities for the two different formulations (i.e. ANC and YEGM) and associated net benefits are shown in Table 4 for four different AEI estimation methods.

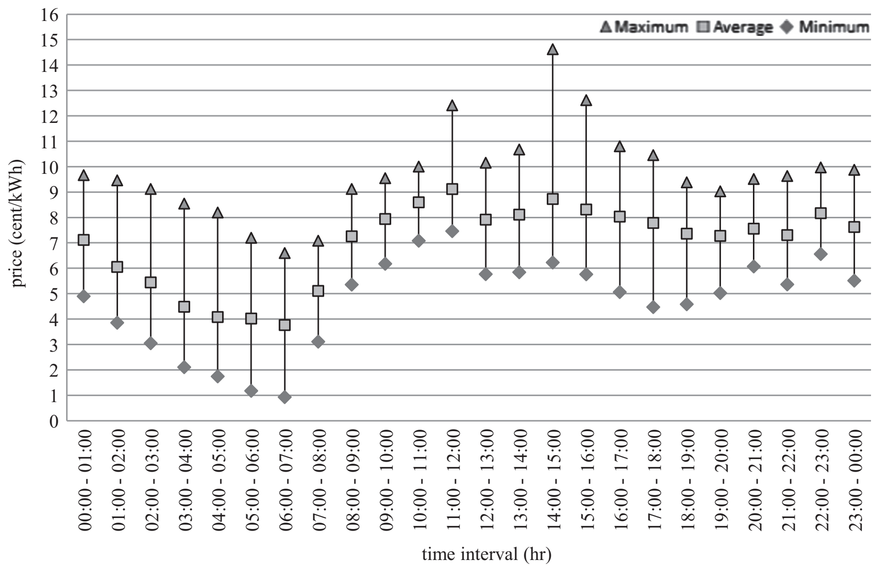

Fig. 3. Hourly electricity prices in Turkey (July 2010–June 2011) [30].

Table 4
The best installed capacities and corresponding net benefits.

Formulation and methods	Installed capacity (MW)	Net benefit(TL)
YEGM formulation		
YEGM method	49	35,133,989
DSI method	91	21,625,056
SPM	67	25,394,919
VPM	64	19,725,802
ANC formulation		
YEGM method	48	16,932,390
DSI method	87	14,411,844
SPM	72	22,557,670
VPM	69	17,187,818

4. Results and discussions

The best installed capacities obtained by using the YEGM method, the DSI method, the SPM and the VPM for Altiparmak HEPP are quite different as can be seen in Table 4. This is due to utilization of different energy income estimation methods. For the YEGM and DSI methods, although the equation used for energy income estimation is the same (Eq. (2)) the unit prices for firm and secondary energies and peak power benefits are quite different (Table 3). In addition, different formulas are used by YEGM and DSI to estimate peak power.

The DSI method uses installed capacity instead of the amount of energy generated for the estimation of peak power (see Eq. (3)). Thus, the higher the installed capacity, the more the benefits are in the DSI method. This is the reason why higher installed capacities are identified as the best alternatives in this method (91 MW and 87 MW for the YEGM and ANC formulations, respectively). The YEGM method utilizes firm energy generation rather than installed capacity in peak power estimation (see Eq. (1)). Therefore, higher installed capacities which do not considerably increase firm energy generation are not financially favorable in the YEGM method, and large installed capacities are not preferred in this method (49 MW and 48 MW for YEGM and ANC formulations, respectively). In addition, higher installed capacities lead to higher amounts of secondary energy generation but YEGM assigns lower benefits to secondary energy generation. Thus, the YEGM method results in smaller installed capacities and seems to be a more reasonable approach for energy income estimation compared to the DSI method.

The YEGM and DSI methods are both based on the incomes from firm and the second energy generation. As previously explained, firm energy is guaranteed for a certain period of the day, thus is more valuable than secondary energy. Secondary energy is generated only after firm energy is satisfied. If the HEPP under consideration has an objective to satisfy a firm energy demand, then utilization of YEGM or DSI methods in the economic analysis will be reasonable. However, if the goal is to maximize annual energy generation then these two methods may not provide realistic net benefit estimates. Thus, the goal(s) of the HEPP—whether to supply firm energy demand or to maximize annual energy generation—should guide the selection of the energy income estimation method.

When hydropower is planned to meet a large portion of the system load, firm energy generation becomes very important. Secondary energy is comparatively less valuable in these systems. On the other hand when hydropower represents a small portion of the total energy generation, maximizing the annual average energy generation should be the main goal [26]. Thus in such a system, hydropower is commonly planned for meeting the peak load demand and it is not used to supply firm energy demand. In Turkey, hydropower is used for supplying peak loads, rather than fulfilling firm energy demand. Therefore, YEGM and DSI methods which require satisfaction of firm energy demand first do not represent the actual situation in Turkey. Maximization of the annual energy generation is a more realistic goal for HEPPs in Turkey. Unlike the YEGM and the DSI methods, SPM and VPM aim to maximize total energy generation, thus they are more suitable.

The SPM assumes that the variation in electricity prices within a day is not significant and assigns a fixed price (8.25 US cent/kWh) to each kWh of energy generated. ANC examined the average energy price of the last 12 months and used a price higher than the average value as the fixed price. However, justification of this selection was not clear and in practice, it is hard to identify a fixed price that is representative of the whole year. The VPM method suggests a systematic approach for including the impact of price variations in energy income estimation.

5. Conclusions

This study provides a review of YEGM and DSI methods for energy income estimation of HEPPs in Turkey. Both methods assume fixed prices for electricity. However, estimating energy income based on a fixed price or different prices for firm and secondary energies do not represent the real situation in Turkey. Regardless of the type of energy—either firm or secondary – electricity is sold in the market according to hourly prices established with respect to the supply and demand bids collected for that hour. In this study, a new method, namely VPM which utilizes hourly electricity prices for energy income estimation is developed and used to estimate energy incomes of Altiparmak HEPP. The advantages and disadvantages of all of these energy income estimation methods and their appropriateness in Turkey are discussed. As a result, it is concluded that the VPM provides a more realistic approach for conducting economic analysis of HEPPs in Turkey since it takes into account hourly fluctuations in energy prices.

References

[1] General Directorate of State Hydraulic Works (DSI). Water and DSI. General Directorate of State Hydraulic Works, Ankara; 2009.
[2] Briscoe J. The financing of hydropower, irrigation, and water supply infrastructure in developing countries. Int J Water ResourDev 1999;15(4):459–91.
[3] Uzlu E, Akpinar A, Komurcu MI. Restructuring of Turkey's electricity market and the share of hydropower energy: the case of the Eastern Black Sea Basin. Renew Energy 2011;36:676–88.
[4] Government web site for legislation: 〈http://www.mevzuat.gov.tr/Kanunlar.aspx〉.
[5] General Directorate of State Hydraulic Works (DSI). Energy Sources, posted 2013. Retrieved from 〈http://www.DSI.gov.tr/docs/hizmet-alanlari/enerji.pdf?sfvrsn=2〉 [accessed May 2014].
[6] (Basak Dam and HEPP Feasibility Report). Ankara: General Directorate of Electrical Power Resources Survey and Development Administration; 2007.
[7] (Balkusan HEPP Final Design Report). Ankara: Hidromark Engineering and Consultancy Company and Ltd; 2010.
[8] (Ekinci HEPP Feasbility Report). Ankara: Eser Project and Engineering Co. Inc; 2009.
[9] Deloitte. Turkish Electricity Market: Developments and Expectations 2010–2011.
[10] Kentel E, Alp E. Hydropower in Turkey: economic, social and environmental aspects and legal challenges. Environ Sci Policy 2013;31:34–43.
[11] Kucukali S, Baris K. Assessment of small hydropower (SHP) development in Turkey: laws, regulations and EU policy perspective. Energy Policy 2009;37:3872–9.
[12] Baris K, Kucukali S. Availability of renewable energy sources in Turkey: current situation, potential, government policies and the EU perspective. Energy Policy 2012;42:377–91.
[13] Ozyurt O. Energy issues and renewables for sustainable development in Turkey. Renew Sustain Energy Rev 2010;14:2976–85.
[14] Yuksel I. Renewable energy status of electricity generation and future prospect hydropower in Turkey. Renew Energy 2013;50:1037–43.
[15] Capik M, Yilmaz AO, Cavusoglu I. Hydropower for sustainable energy development in Turkey: the small hydropower case of the Eastern Black Sea Region. Renew Sustain Energy Rev 2012;16:6160–72.
[16] (Altiparmak HEPP Feasibility Report). Ankara: General Directorate of Electrical Power Resources Survey and Development Administration; 2001.
[17] Ak M. (M.S. Thesis). Alternative Feasibility Studies for Altiparmak Dam and HEPP. Ankara: Middle East Technical University; 2011.
[18] Government of Nepal. Guidelines for Study of Hydropower Projects.. Kathmandu: Ministry of Water Resources Department of Electricity Development; 2003 (December).
[19] Energy for Sustainable Development Limited. Richmond Hydro Feasibility Study—Final Report. October; 2005.
[20] Karlis AD, Papadopoulos DP. A systematic assessment of the technical feasibility and economic viability of small hydroelectric system installations. Renew Energy 2000;20:253–62.
[21] Aydin BE. (M.S. Thesis). Feasible study of multiple hydropower projects: case study of baltaci stream, Trabzon, Turkey. Ankara: Middle East Technical University; 2010.
[22] Altiparmak HEPP Feasibility Study. Ankara: Yolsu Engineering Services Ltd. Co; 2009.
[23] Karamouz M, Szidarovszky F, Zahraie B. Water resources system analysis. United States: CRC Press; 2003.
[24] US Army Corps of Engineers (USACE). Determining Energy Potential. Engineering and Design—Hydropower, United States; 1985.
[25] ESHA. Stream flow characteristics. State of the art of small hydropower in EU-25. Brussels: European Small Hydropower Association; 2004.
[26] US Army Corps of Engineers (USACE). Engineering and Design-Hydropower. Washington, DC: US Army Corps of Engineers; 1985.
[27] Bakir, NN Turkey's Hydropower Potential. Turkey's Hydropower Potential and Review of Electricity Generation Policies from EU Perspective; 2010, 〈http://www.ere.com.tr/pdf/HIDRO-POT-AB-EN.pdf〉, [accessed 26.04.12].
[28] Pekcagliyan MD. Optimum installed capacity selection and economic analysis for hydroelectric power plants. Lecture notes of CE 571 hydropower engineering. Ankara: Middle East Technical University; 2011.
[29] Yanmaz AM. Applied water resources engineering. Ankara: METU Press; 2006.
[30] Market Financial Settlement Center (PMUM). SGOF and SMF Listing; 2012, 〈http://dgpys.teias.gov.tr/dgpys/〉, (accessed April 2012).
[31] Erdogdu E. A paper on the unsettled question of Turkish electricity market: Balancing and settlement system (Part I). Appl Energy 2010;87:251–8.
[32] Camadan E, Erten IE. An evaluation of the transitional Turkish electricity balancing and settlement market: Lessons for the future. Renew Sustain Energy Rev 2011;51:1325–34.
[33] USAID (US Agency International Development). USAID Hydropower Investment Promotion Project (HIPP). Turkish Electricity Price Curve Analysis (2010–2011). USAID/CAUCASUS office of Energy and Environment; March 9, 2012.
[34] Carbaugh RJ. Contemporary economics—an applications approach. 7th Ed. Armonk, New York: M.E. Sharpe; 2014.
[35] Olivares MA. (Ph.D. Thesis). Optimal hydropower reservoir operation with environmental requirements. California: University of California at Berkeley; 2008.
[36] Grygier JC, Stedinger JR. Algorithms for optimizing hydropower system operation. Water Resour Res 1985;21(1):1–10.
[37] Trezos T, Yeh WW-G. Use of stochastic dynamic-programming for reservoir management. Water Resour Res 1987;23(6):983–96.
[38] Jacobs J, Steinberg R. Socrates: a System for scheduling hydroelectric generation under uncertainty. Ann Oper Res 1995;59:99–133.